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A MORPHOMETRIC STUDY OF SILVER HAKE

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ABSTRACT

Evidence is presented that the silver hake population along the Atlantic coast is comprised of two separate groups. One group inhabits the waters off the New England coast and the other is found off the southern New England, New York, and New Jersey coasts. Two characters, head length and pelvic fin length, gave consistent differences for separating these groups during two seasons of the year. The data were analyzed by appropriate F-tests in an analysis of covariance and by a T-test for the distance between regression lines.

INTRODUCTION

A program of research on the biology of the silver hake (*Merluccius bilinearis*, Mitchill) was initiated in 1955 at the Fish and Wildlife Service, Bureau of Commercial Fisheries, Biological Laboratory, Woods Hole, Massachusetts. This species is fished commercially in the coastal waters from Maine to New Jersey and is processed largely for human consumption with lesser amounts being used for animal food and industrial purposes. One of the research aims was to determine if the silver hake caught by the commercial fishing fleet consist of one or more than one population. In the present study, morphometric data from the Gulf of Maine, Rhode Island, New York, and New Jersey are compared.

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MATERIALS AND METHODS

Silver hake used in this study were collected from pound nets, weirs, and otter trawlers from Maine to New

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Jersey. Additional collections were made on cruises of the *Albatross III* in 1955 and 1956. Care was taken to correctly identify the silver hake and not include the American or offshore hake, *Merluccius albidus*, in this study. The location and description of each sample are shown in figure 1 and table 1.

The characters measured conformed to the descriptions of Hubbs and Lagler (1947) and are listed in table 2. The fork length was used as the independent variable in all comparisons; all other characters measured were employed as dependent variables. The statistical methods outlined in Snedecor (1946) for the covariance analysis and a T-test described by Quenouille (1950) to determine the significance of the distance between regression lines were used.

The original data were plotted to determine the relationship of the various dependent variables on the independent variable. A linear relationship was found to exist between variables for silver hake from 26 to 38 centimeters. Accordingly, only those fish in the sample between 26 and 38 centimeters in length were used in this study and approximately 25 fish were collected in each 1-centimeter size group at each sampling location.

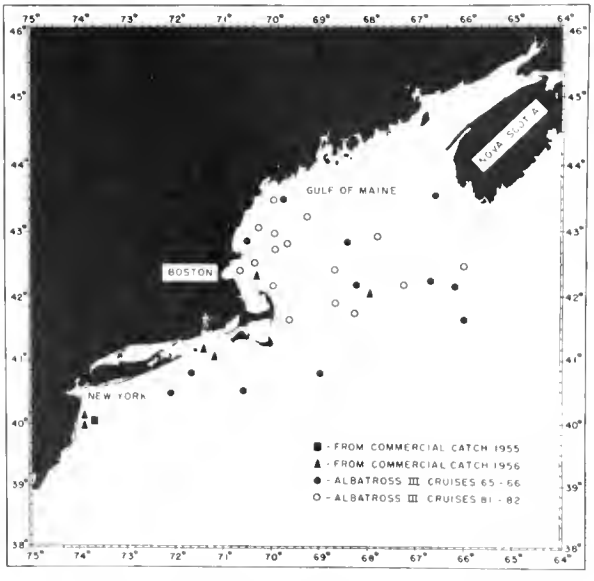

Figure 1.--Sampling locations and source of samples for the silver hake used in this study.

Quenouille outlines two assumptions that must be fulfilled in order to use the T-test between regression lines: (1) The variance of the samples must be comparable, when the larger variance of the two is divided by the smaller, the resulting F-ratio should not be significant; (2) the regression coefficients must not be significantly different. The above assumptions were fulfilled for head length and length of the pelvic fin only; all other parameters failed to meet these assumptions.

If conditions 1 and 2 are met then the variances and coefficients may be pooled and the two regression lines recomputed using a mutual regression coefficient. The difference between the lines may then be computed simply by subtracting values of one formula from that of the other. The difference is then tested to determine if it is significantly different from zero. An example of the application of this test using data from the present study is given in table 3.

To further determine whether or not there are significant differences between the silver hake collected from the Gulf of Maine and those from Rhode Island to New Jersey, covariance analyses of eight morphometric characters were calculated for each area. These analyses are summarized in table 4. Those characters showing a difference at the 1-percent level or higher were head length, length of the pelvic fin, length of the first ventral fin, and eye diameter. These four characters were used to separate the groups. The T-test was applied to only two of the characters, head length and length of the pelvic fin. The other two characters, eye diameter and length of the first ventral fin, were not applicable since the variance of the samples was too great.

RESULTS

Following Marr's (1957) suggestion, the term "group" will be used to define the various fractions of the population since the distinctive characteristics cannot be classed as being either phenotypic or genotypic.

TABLE 1.--Location, date, and number of silver hake used for racial analysis

Date		Cruise number	Location	Lat. N.	Long. W.	Total sample	Fish measured
				Albatross III			
1955							
Sept.	8	65	Gulf of Maine	42°49'	70°37'	185	20
	10			43°27'	69°43'	120	18
	10			42°52'	68°25'	60	20
	11			43°38'	66°34'	75	20
	13			42°09'	66°11'	9	8
	13			42°13'	66°41'	95	21
	14			42°09'	68°16'	81	21
	22			41°38'	65°59'	32	22
	24			40°48'	68°59'	6	1
	25	66	Southern Rhode Island	40°33'	70°36'	155	20
	28			40°29'	72°06'	36	10
	28			40°48'	71°40'	124	10
1956							
Nov.	2	81-	Gulf of Maine	42°24'	70°40'	43	32
	2	82	(Inshore)	42°33'	70°20'	125	48
	3			43°04'	70°17'	188	24
	3			43°28'	69°58'	115	18
	3			43°14'	69°15'	90	79
	4			42°58'	69°56'	40	14
	4			42°43'	69°56'	24	19
	4			42°48'	69°39'	52	26
	8			42°10'	69°57'	10	10
	14			41°38'	69°37'	34	20
	8	do.	Gulf of Maine	42°25'	68°40'	109	60
	9		(Offshore)	42°54'	67°47'	42	25
	9			42°09'	67°16'	10	6
	9			41°44'	68°15'	126	59
	14			41°53'	68°39'	162	43
	15			42°27'	65°59'	15	6
	17	do.	Southern Rhode Island	40°50'	70°13'	257	65
	17	do.	Long Island Area	40°23'	73°13'	238	30
	18			40°23'	73°34'	19	12
				Commercial trawler			
1955							
Nov.	27	--	Newport, Rhode Island	---	---	20	20
Dec.	19	--	Seaside, New Jersey	---	---	120	104
	20	--	Belmar, New Jersey	---	---	90	90
1956							
Apr.	5	--	Pt. Pleasant, N.J.	---	---	38 Bushel	100
	16	--	Gulf of Maine	---	---	185	55
May	2	--	Pt. Judith, R.I.	---	---	167	109

TABLE 2.--Body proportions used in the study for separating groups of silver hake

[+ data analyzed; - insufficient data]

Variables	Data on hand	Covariance analysis	T-test
Independent:			
Fork length	1955-1956	+	+
Dependent:			
Head length	1955-1956	+	+
Snout length	1955 only	+	-
Snout to anal opening	1955 only	+	-
Snout to insertion of pelvic fin	1955 only	+	-
Snout to insertion of pectoral fin	1955 only	+	-
Fin, first dorsal, length	1956 only	+	+
Fin, first dorsal, height	1956 only	+	+
Fin, second dorsal, length	1956 only	+	+
Fin, second dorsal, height	1956 only	+	+
Fin, third dorsal, length	1956 only	+	+
Fin, third dorsal, height	1956 only	+	+
Fin, pectoral, length	1956 only	+	+
Fin, pelvic, length	1956 only	+	+
Fin, first ventral, length	1956 only	+	+
Fin, first ventral, height	1956 only	+	-
Fin, second ventral, length	1956 only	+	-
Fin, second ventral, height	1956 only	+	-
Eye diameter	1956 only	+	-

Head Length

Covariance analysis between inshore and offshore samples collected in the Gulf of Maine was not significant (table 4). Assuming that the Gulf of Maine consists of only one group, these data were compared with samples taken from Nantucket Shoals (west) and the resulting "F" value was significant. The Gulf of Maine data were compared with the samples taken from Rhode Island, New York, and New Jersey, and the results of the covariance analysis were highly significant. However, no significant difference was found between the samples collected from Rhode Island and those taken from New Jersey, nor between the Nantucket Shoals and New York samples. The plotted regression lines of the samples collected from the Gulf of Maine, Rhode Island, and New York-New Jersey are shown in figure 2.

The results of the T-test for the distance between regression lines for the Gulf of Maine and the Rhode Island-New Jersey samples were found to be highly significant, as shown in table 5. However, a comparison between two closely associated areas, Rhode Island and New Jersey, was not significant. These results indicate that the silver hake in the Gulf of Maine are significantly different with regard to head length from the silver hake found along the southern New England, New York, and New Jersey coasts and that this parameter can be used to separate these two groups.

Length of Pelvic Fin

The plotted regression lines for length of the pelvic fin against total length are presented in figure 2. The Rhode Island and New Jersey samples

TABLE 3.--An example, using data on head length from the present study, showing how the Quenouille T-test for the separation of regression lines of similar slope can be employed for racial studies in fishery investigations

Parameter, location and date	F (formula 1) between variances	T (formula 2) between coefficients	T (formula 3) between lines
Gulf of Maine September 1955 New Jersey October 1955	1.386 NS	0.0166 NS	26.462**
Gulf of Maine April 1956 New Jersey April 1956	1.052 NS	0.0061 NS	32.495**

Formulae:

(1) $F = \frac{V \text{ (larger)}}{v \text{ (smaller)}} = \frac{\Sigma y^2 - \frac{(\Sigma xy)^2}{x^2}}{n-2}$ where $V = sy \cdot x^2$

(2) $T = b_1 - b_2$ where $(sdy \cdot x^2) / N_1 + N_2 - 4$

$$\sqrt{\frac{v_{1.2}}{N_1} + \frac{V_{1.2}}{N_2}}$$

(3) $$T = \frac{\bar{Y}_1 - \bar{Y}_2 \hat{b} (\bar{x}_1 - \bar{x}_2)}{s\hat{y} \cdot x^2 \left(\frac{1}{N_1} + \frac{1}{N_2} + \frac{\bar{x}_1 - \bar{x}_2}{\Sigma x^2_1 \ \Sigma x^2_2} \right)}$$

where $b = \frac{\Sigma x_1 y_2 + \Sigma x_2 y_2}{\Sigma x^2_1 + \Sigma x^2_2}$ and

$$s\hat{y} \cdot x^2 = \frac{(\Sigma x_1 \cdot y_1 + x_2 \cdot y_2)^2}{\Sigma x^2_1 + \Sigma x^2_2}$$

Symbols used are: ** - significant at the 1 percent level, and
NS - not significant.

do not differ significantly, but when compared with the Gulf of Maine collection the results were highly significant (table 4).

The T-test was also applied to this parameter and the comparisons with the Gulf of Maine with the total southern collection (Nantucket Shoals, New York, and New Jersey) were found to be highly significant (table 5).

Length of First Ventral Fin

Comparisons were made with silver hake collected in the northern area (Gulf of Maine) and those from Rhode

Table 4.--Analysis of covariance. Silver hake taken in the waters of the Gulf of Maine and in the coastal waters of Rhode Island, Long Island, New York, and New Jersey

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio "F"
HEAD LENGTH				
Gulf of Maine (offshore) September 1955 with New Jersey, December 1955				
Difference for homogeneity between regions	1		395.37	75.208**
Regression within regions	296	1556.22	5.257	
Total regression among regions	297	1951.59		
Gulf of Maine (offshore) with New Jersey, April 1956				
Difference for homogeneity between regions	1		192.56	45.022**
Regression within regions	331	1415.95	4.277	
Total regression among regions	332	1608.51		
Gulf of Maine (offshore) April 1956 with Rhode Island, May 1956				
Difference for homogeneity between regions	1		392.05	88.474**
Regression within regions	357	1581.95	4.431	
Total regression among regions	358	1974.87		
Rhode Island, May 1956 and New Jersey, April 1956				
Difference for homogeneity between regions	1		.540	.1255 NS
Regression within regions	300	1292.92	4.310	
Total regression among regions	301	1293.46		
Nantucket Shoals (west) with New York-Long Island, November 1956				
Difference for homogeneity between regions	1		9.27	.2161 NS
Regression within regions	112	4804.83	42.900	
Total regression among regions	113	4814.10		
Gulf of Maine (offshore) with Gulf of Maine (inshore) November 1956				
Difference for homogeneity between regions	1		1.44	.2327 NS
Regression within regions	485	3000.76	6.187	
Total regression among regions	486	3002.20		
Gulf of Maine (offshore) with Nantucket Shoals (west) November 1956				
Difference for homogeneity between regions	1		22.65	4.357 *
Regression within regions	261	1356.51	5.198	
Total regression among regions	262	1379.16		

Table 4. --Analysis of covariance. Silver hake taken in the waters of the Gulf of Maine and in the coastal waters of Rhode Island, Long Island, New York, and New Jersey (continued)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio "F"
Gulf of Maine (offshore) with New York-Long Island, November 1956				
Difference for homogeneity between regions	1		24.38	5.219*
Regression within regions	244	1139.67	4.671	
Total regression among regions	245	1164.05		
Gulf of Maine (inshore) with New York-Long Island, November 1956				
Difference for homogeneity between regions	1		162.83	24.459**
Regression within regions	336	2236.92	6.657	
Total regression among regions	337	2399.75		
LENGTH OF PELVIC FIN				
Gulf of Maine (offshore) with New Jersey, April 1956				
Difference for homogeneity between regions	1		26.39	7.080**
Regression within regions	331	1233.92	3.727	
Total regression among regions	332	1260.31		
Rhode Island, May 1956, with New Jersey, April 1956				
Difference for homogeneity between regions	1		3.99	.724 NS
Regression within regions	300	1653.44	5.511	
Total regression among regions	301	1657.43		
Gulf of Maine (offshore), April 1956, with Rhode Island, May 1956				
Difference for homogeneity between regions	1		37.55	6.359*
Regression within regions	358	2114.24	5.905	
Total regression among regions	359	2151.79		
Gulf of Maine (offshore) November 1956 with Gulf of Maine (inshore)				
Difference for homogeneity between regions	1		15.03	1.935 NS
Regression within regions	485	3767.07	7.767	
Total regression among regions	486	3782.10		
Gulf of Maine (offshore) with New York-Long Island, November 1956				
Difference for homogeneity between regions	1		1014.81	233.45**
Regression within regions	244	1060.76	4.347	
Total regression among regions	245	2075.57		

Table 4. --Analysis of covariance. Silver hake taken in the waters of the Gulf of Maine and in the coastal waters of Rhode Island, Long Island, New York, and New Jersey (continued)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio "F"
Gulf of Maine (offshore) with Nantucket Shoals (west), November 1956				
Difference for homogeneity between regions	1		996.66	218.30**
Regression within regions	261	1191.56	4.565	
Total regression among regions	262	2188.12		
Nantucket Shoals (west) with New York-Long Island, November 1956				
Difference for homogeneity between regions	1		8.35	1.540 NS
Regression within regions	112	607.31	5.422	
Total regression among regions	113	615.66		
Gulf of Maine (inshore) with New York-Long Island, November 1956				
Difference for homogeneity between regions	1		73.73	11.550**
Regression within regions	337	2151.13	6.383	
Total regression among regions	338	2224.86		
LENGTH OF FIRST VENTRAL FIN				
Gulf of Maine (offshore) with New Jersey, April 1956				
Difference for homogeneity between regions	1		119.96	8.749**
Regression within regions	331	4538.28	13.710	
Total regression among regions	332	4658.24		
Gulf of Maine (offshore), April 1956 with Rhode Island, May 1956				
Difference for homogeneity between regions	1		129.97	9.028**
Regression within regions	358	5154.02	14.396	
Total regression among regions	359	5283.99		
Rhode Island, May 1956, with New Jersey, April 1956				
Difference for homogeneity between regions	1		7.960	.4875 NS
Regression within regions	300	4898.48	16.328	
Total regression among regions	301	4906.44		
Nantucket Shoals (west) with New York-Long Island, November 1956				
Difference for homogeneity between regions	1		54.30	3.709 NS
Regression within regions	112	1639.55	14.638	
Total regression among regions	113	1693.85		

Table 4.--Analysis of covariance. Silver hake taken in the waters of the Gulf of Maine and in the coastal waters of Rhode Island, Long Island, New York, and New Jersey (continued)

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Variance ratio "F"
RIGHT EYE DIAMETER				
Gulf of Maine (offshore), April 1956 with Rhode Island, May 1956				
Difference for homogeneity between regions	1		5.93	10.102**
Regression within regions	358	210.49	.587	
Total regression among regions	359	216.42		
Rhode Island, May 1956, with New Jersey, April 1956				
Difference for homogeneity between regions	1		.230	.4175 NS
Regression within regions	300	165.27	.551	
Total regression among regions	301	165.50		

Symbols used are: * - significant at the 5 percent level, ** - significant at the 1 percent level, and NS - not significant.

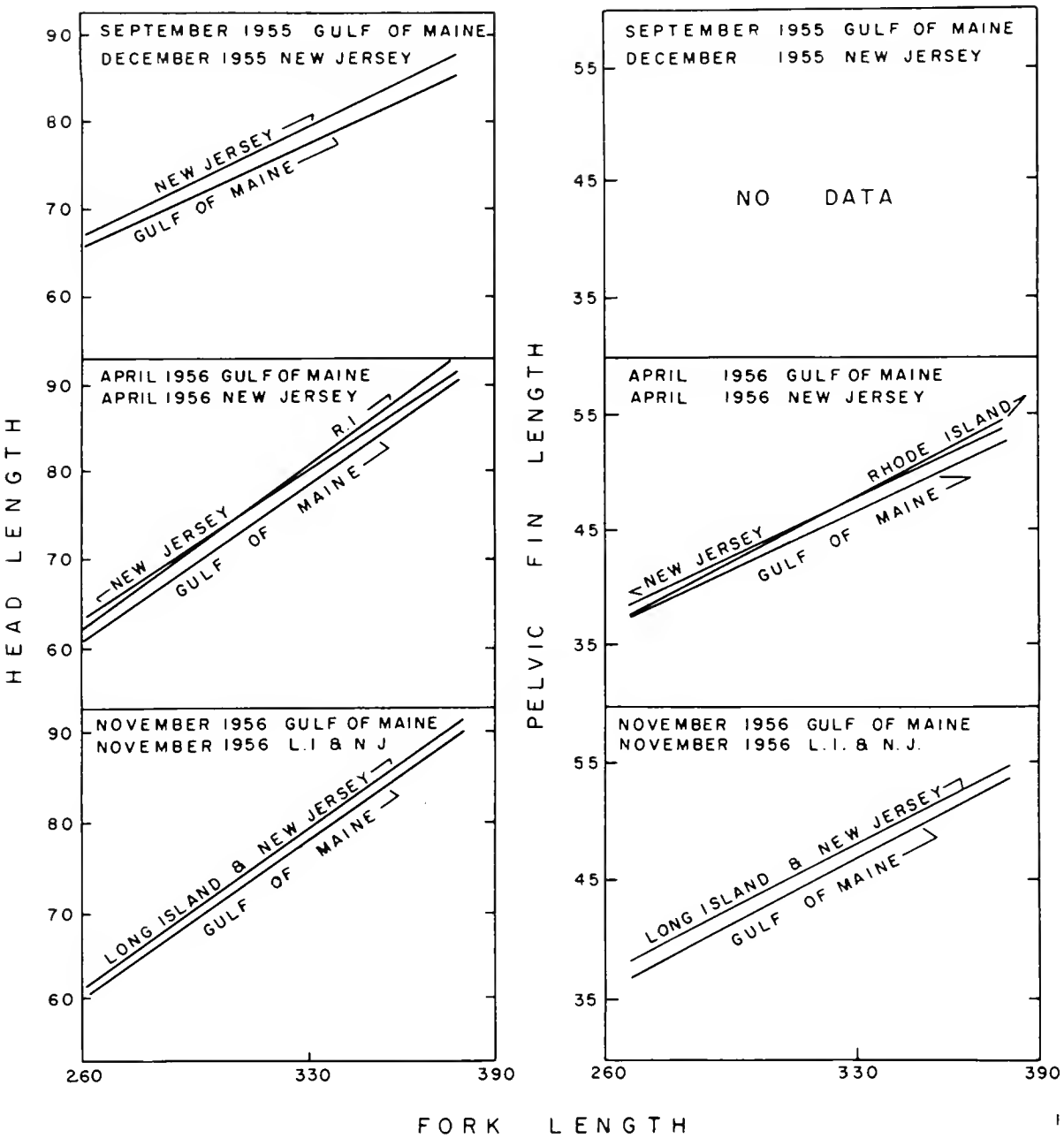

Figure 2.--Plotted regression lines for head length (left) and pelvic fin length (right) on fork length from silver hake samples taken from the Gulf of Maine, Rhode Island, Long Island, and New Jersey waters.

Island and New Jersey. The resulting "F" value was significant at the 5-percent level. The Rhode Island and New Jersey collections were also compared and the resulting "F" value was not significant (table 4). These results indicate that this characteristic can also be used in separating the two groups. The variance of these comparisons was too large to apply the T-test.

Eye Diameter

The same comparisons were made for this character as for the ventral fin. The resulting "F" value was significant for the comparisons between the northern and southern samples, but was not significant when the two southern samples were compared against each other (table 4). The

Table 5. --Analysis of distance between regression lines. Silver hake taken in the Gulf of Maine and in the coastal waters of Rhode Island, Long Island, New York, and New Jersey (See table 3 for explanation.)

Source of variation	Degrees of freedom	Variance ratio (between)	"T" value slopes (between)	"T" value lines (between)
HEAD LENGTH				
Gulf of Maine (offshore) September 1955 with New Jersey, December 1955				
Difference for homogeneity between regions	1	1.386 NS	0.0166 NS	26.462 **
Regression within regions	296			
Total regression among regions	297			
Gulf of Maine (offshore) April 1956 with New Jersey, April 1956				
Difference for homogeneity between regions	1	1.052 NS	0.0061 NS	32.495 **
Regression within regions	331			
Total regression among regions	332			
Gulf of Maine (offshore) April 1956 with Rhode Island, May 1956				
Difference for homogeneity between regions	1	1.000 NS	0.0679 NS	38.352 **
Regression within regions	357			
Total regression among regions	358			
Rhode Island, May 1956 with New Jersey, April 1956				
Difference for homogeneity between regions	1	1.046 NS	0.0577 NS	1.554 NS
Regression within regions	300			
Total regression among regions	301			
Gulf of Maine (offshore) with Gulf of Maine (inshore), November 1956				
Difference for homogeneity between regions	1	1.534 **	0.2234 *	Data unsuitable
Regression within regions	485			
Total regression among regions	486			
Gulf of Maine (offshore) with Nantucket Shoals (west), November 1956				
Difference for homogeneity between regions	1	1.367 NS	0.0316 NS	17.921 **
Regression within regions	261			
Total regression among regions	262			
Nantucket Shoals (west) with New York-Long Island, November 1956				
Difference for homogeneity between regions	1	1.422 NS	0.0365 NS	1.715 NS
Regression within regions	112			
Total regression among regions	113			

Table 5. --Analysis of distance between regression lines. Silver hake taken in the Gulf of Maine and in the coastal waters of Rhode Island, Long Island, New York, and New Jersey (See table 3 for explanation.) (continued)

Source of variation	Degrees of freedom	Variance ratio (between)	"T" value slopes (between)	"T" value lines (between)
Gulf of Maine (inshore) with New York-Long Island, November 1956				
Difference for homogeneity between regions	1	1.239 NS	0.0040 NS	4.018 **
Regression within regions	336			
Total regression among regions	337			
Gulf of Maine (offshore) with New York-Long Island, November 1956				
Difference for homogeneity between regions	1	1.238 NS	0.0478 NS	6.7091 **
Regression within regions	244			
Total regression among regions	245			
LENGTH OF PELVIC FIN				
Gulf of Maine (offshore) with New Jersey, April 1956				
Difference for homogeneity between regions	1	1.5059 **	0.0228 NS	13.836 **
Regression within regions	331			
Total regression among regions	332			
Gulf of Maine (offshore) with Long Island-New York, November 1956				
Difference for homogeneity between regions	1	1.218 NS	0.0047 NS	5.7518 **
Regression within regions	244			
Total regression among regions	245			
Gulf of Maine with Nantucket Shoals (west), November 1956				
Difference for homogeneity between regions	1	1.367 NS	0.0316 NS	17.921 **
Regression within regions	261			
Total regression among regions	262			

Other data comparisons for length of pelvic fin unsuitable for comparison with this test.

Symbols used are: * - significant at the 5 percent level, ** - significant at the 1 percent level, and NS - not significant.

variance of these samples was also too large for the T-test.

CONCLUSIONS

The results of the analysis of the morphometric measurements used in this study indicate that two groups of silver hake may be distinguished, one from the Gulf of Maine and the other south of Cape Cod. Relative differences in head length, length of pelvic fin, length of ventral fin, and eye diameter clearly indicate that the samples taken from the major areas (Gulf of Maine, Rhode Island, New York, New Jersey) were not drawn from the same population. The amount of intermixing between the areas, if any, cannot be determined from the present data. Results from preliminary tagging experiments conducted in both areas have not indicated any movement of silver hake between areas.

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